THE STORY OF CATGUT

By ELDRED J. HOLDER, PH.D., B.PHARM., PH.C.(Edin.)

Historical

The dictionary definition of *catgut* is ' a tough cord made from the intestines of animals, especially sheep.' There may or may not follow an indication of its uses.

Mention catgut to a surgeon and he thinks of a suture material ; to a musician, he recalls the mellow tones of the violin or cello ; to a sportsman and he wonders if he remembered to replace the the press on his tennis racquet. Catgut, to Everyman, prompts speculation as to its feline origin. There is, however, in fact no evidence that the intestine of the cat has ever been used to produce catgut strings. The name can be traced back to the Arabic *cither*, an early stringed instrument. The same root is seen in the old name for the dancing master's fiddle, a *kit*. From *kitgut* to *catgut* is an easy etymological step.

No aid to surgery has had such a chequered career as catgut. It has been in and out of favour, sworn by and sworn at, over a period of some 75 years. Catgut for suturing has been ' going out of fashion ' since the writer first took interest in it some 17 years ago. Nevertheless, more is being manufactured and used today than ever before. Why should this be so ? The answer lies in one special feature—its absorbability in living animal tissues.

Although this absorbability was not realized until comparatively recently, the use of animal intestine as a ' string ' dates back as far as there are records of mankind. Indeed, it is reasonable to assume that its utility would have been recognized long before there was evolved the art of twisting vegetable fibres or hairs into thread. The use of dried intestine as a suture is undoubted even so far back in history as the Papyrus of Ebers, *circa* 3750 B.C. Egyptian surgeons at that time appear to have acquired considerable skill in wound repair.

Susruta, a Hindu writer who lived about 1500 B.C., refers to the use of cotton, drawn copper, horsehair and animal intestines as ligatures. Ferrara, an Italian, at the end of the 16th century used intestines of tortoises amongst other suture materials ; he seems to have had some precognition of the need for sterilizing because he is said to have stored his sutures in wine before use. In France the importance of catgut makers was recognized in 1656 by Louis XIV, who granted letters patent to the Guild whose members supplied racquet makers, clockmakers, musicians, cross-bow makers and surgeons.

A short digression may be permissible to make reference to a natural means of wound closure which has been known for hundreds of years, namely the use of the mandibles of certain species of biting ants. The edges of a wound are brought together manually, the ant is held by its body and allowed to bite across the wound edges ; the moment it has done so the body is twisted away from the head which, with the jaws, is left acting like a modern metal clip. This procedure is still used by the aboriginal natives of central Australia and there are records of its use up to recent times in Greece, Serbia and Algeria.

To return to catgut, it was in 1868, the year before he came to Edinburgh University as Professor of Clinical Surgery, that Joseph Lister experimentally tied catgut round the right carotid artery of a calf. Thirty days later the animal was killed and Lister examined the ligature. At first he thought that it was unchanged, but closer investigation revealed the fact that the catgut was no longer present but had been replaced by a ring of living tissue. Though Lister is mainly remembered for his introduction of antisepsis into surgery, his recognition of the absorbability of catgut has been of fundamental importance in the successful modern use of this material.

He quickly realized also the risk of introducing infection into wounds by the use of ' raw ' catgut. There are records that in 1869 he was using an aqueous solution of phenol as a sterilizing agent for catgut. This would be fairly efficient as a sterilizing agent (except for resistant spores) but would leave the sutures in a waterlogged and weakened condition. Apparently with the idea of overcoming these defects, Lister then used a solution of phenol in olive oil. This would undoubtedly obviate loss of tensile strength but would be even less efficient in sterilization, though the catgut would be ' antiseptic ' and far less dangerous than untreated material. He further anticipated the modern process for ' hardening ' catgut, that is for delaying its rate of absorption in the tissues, by chromicizing by the use of mixtures of phenol and chromic acid solution in

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which the catgut was steeped for varying periods.

Surgical catgut is not easy to ·make. The raw material, sheep's intestine, varies from animal to animal in quality, width and toughness ; it varies according to age, to feeding and so on, and cannot be bulked in order to obtain uniformity. In its natural state it is loaded with bacteria, both pathogenic and non-pathogenic. The problem lies in its complete sterilization without the destruction of the natural properties of the gut. It is manufactured in this country only under Government licence, and the conditions and inspections required leave no doubt as to the bacteriological safety of the final product. Its rate of absorption in the human body is hard to control ; the same strand divided into two pieces and implanted in similar locations in two individuals may have different absorption periods due to idiosyncrasy, sensitivity, vitamin deficiency or cachexia.

Many arguments have been used for and against *non-absorbable* suture materials. They are often less expensive and more easily sterilized than catgut, they can be of absolutely standard size and tensile strength. If buried, however, they remain permanently in the tissues and may at any time subsequently become a focus for infection.

Two further points regarding non-absorbable sutures are worth noting. First, the harshness of monofilaments such as silk-worm gut. Harshness, that is, to the patient, for if the stitches are on the surface the cut ends tend to harden and may catch in the dressings ; if such materials are used for buried sutures there is a grave risk of the sharp points of the cut ends doing damage to adjacent tissues, particularly to blood vessels. The other point concerns the softer and generally preferable braided materials such as braided silk. Even in interrupted sutures of such materials there is the possibility of bacteria finding refuge in their interstices, whilst in continuous sutures the movement of serum along the suture material by capillary action favours the spread of any incidental infection. If, to eliminate this wick-like action, the braided material has been rendered non-capillary, the disadvantage disappears and gives probably the ideal form of non-absorbable suture.

The ideal suture material is one which will retain its holding power until healing is complete and will then disappear with a minimum of disturbance to the tissues. Until a substitute is found, either natural or synthetic, which has superior physical qualities *as well as* absorbability, catgut is likely to remain the most popular and valuable of all suture and ligature materials.

For a detailed and comprehensive history of sutures, and especially of catgut, through the ages, the reader is confidently referred to ' Le Catgut ' by Dr. A. Fandré (1944).

Manufacture

There are two main stages in the production of a sterile suture ; first the manufacture of the strand, then its sterilization and preparation for use at operation.

A cross section of sheep's intestine reveals three main layers ; the outer mesenteric coat whereby the intestine is ' slung ' within the abdominal cavity; the middle (sub-mucous and muscular) layer which is thin, elastic and muscular ; and the inner, absorptive mucous layer.

In preparation the gut is split longitudinally into ribbons and by carefully controlled scraping operations the outer mesenteric and inner mucous coats are removed. The sub-mucous, muscular ribbons are twisted, sometimes singly, more often in twos, threes or fours, then stretched and dried to form an almost solid filament. Thereafter the strings must be polished to give uniformity of diameter along the strand and a smooth surface, but not too smooth or the knot may slip after suturing with the risk of a disaster such as a ' burst abdomen.' Finally the strands are sorted into gauges to agree with the size standards in the British Pharmaceutical Codex and the United States Pharmacopoeia.

Until 1944 British manufacturers each had their own catgut size standards with the result that one maker's No. 1 might be equivalent to another maker's No. 3, and so on. During the recent war, standards for gauge and tensile strength were drawn up and included in the Sixth Supplement, 1944, to the British Pharmaceutical Codex, 1934 edition. The B.P.C. size standards are nearly identical with those of the United States Pharmacopoeia which, in addition to reducing confusion amongst British makes, was a useful contribution towards international co-operation.

Deliberate hardening to delay the rate of absorption in the tissues is referred to later and is usually done during manufacture of the raw catgut strings.

Sterilization

A phrase often used by makers and users of surgical catgut is ' the catgut problem.' This expression summarizes the difficulty of devising a sterilizing process which is rigorous enough to kill the most resistant sporing organisms without also damaging the tensile strength of the strand.

What is the bacteriological flora of unsterilized catgut ? Primarily it is that of the contents of the intestine in the living animal. The non-sporing organisms, staphylococci, streptococci, B. coli, etc., may be disregarded. Whatever their pathological
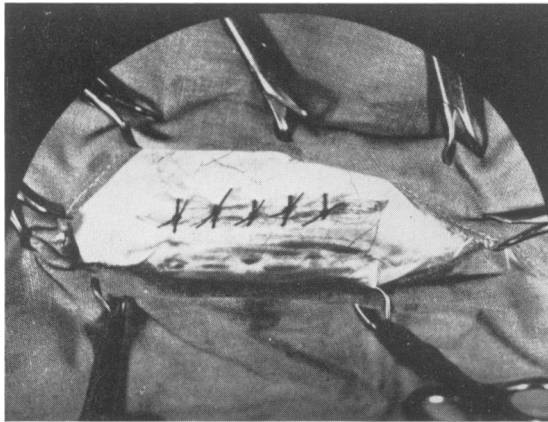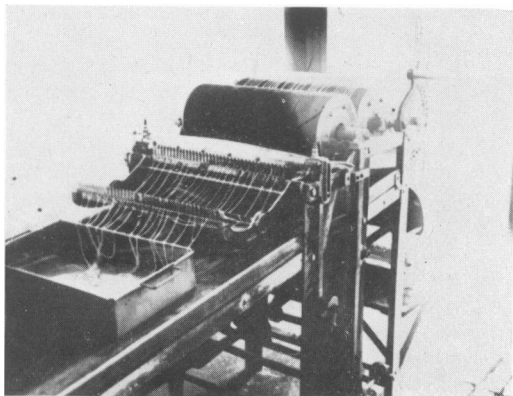
In vivo digestion test

Chromic catgut stitches in dorso-lumbar muscle of rabbit ten days after implanting.

Note freedom from local reaction.
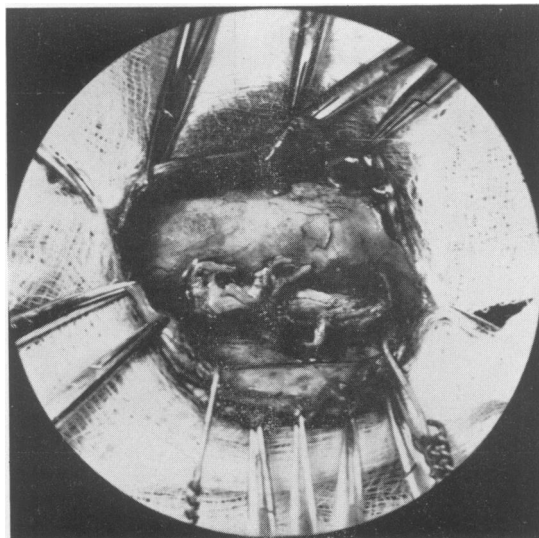
In vivo digestion test

Thick, plain catgut stitches seven days after operation showing accumulation of detritus.
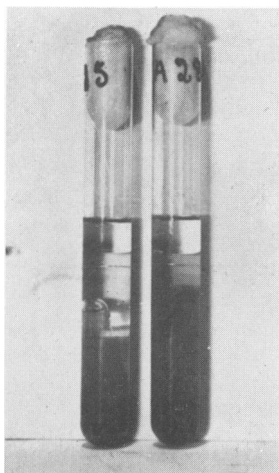
Manufacture of catgut strings

Splitting the sheep intestine into ribbons.

Manufacture of catgut strings

Machine for cleaning intestinal ribbons.

Bacteriological testing of catgut

The illustration shows a muscle-broth medium with paraffin seal for aerobic/anaerobic test.

significance in human ailments, they are comparatively easy to kill in catgut. Even if they survived other processes of manufacture, the alcoholic fluid normally present in the sealed tube containing the finished suture would kill all but sporing organisms.

Spores are normally *not* killed by alcohol (Williams, 1936) which to them is merely another kind of anhydrous state, and it is precisely for such a condition that the dormant spore stage is designed. This point may still not be fully appreciated as is apparent from the continued popularity of rinsing with alcohol or ether as a means of ' sterilizing ' hypodermic syringes.

Theoretically, if the faecal and pre-faecal contents of the intestine could be entirely removed at the moment of death, the gut should be sterile. In practical slaughterhouse conditions this is impossible as is shown by cultures obtained from raw catgut strings. Both anaerobic and aerobic spores may be present, the most spectacular and alarming being *Clostridium tetani*.

The presence of tetanus bacilli in bowel contents has been demonstrated often enough. Yet thousands of samples of raw catgut strings can be tested without finding it. Moreover, in many years of experience the writer has yet to find a case of tetanus in which imperfectly sterilized catgut could reasonably be blamed as the source of the infection. Nevertheless, the wise manufacturer treats every strand as though it were loaded with the most resistant spores known.

Other pathogenic anaerobes such as *Cl. welchii*, *Cl. sporogenes* and *Cl. oedematis maligni* are commonly present in unsterilized catgut.

The sporing aerobes, which are mostly non-pathogenic, include in addition to varieties of *B. subtilis*, *B. mesentericus ruber* which is sometimes called the ' catgut bacillus,' being very common and giving, in broth culture, a distinctive off-white pellicle with a red line running through it. From experimental work it has been found that aerobic spores are more resistant than those of anaerobes. In control bacteriological tests on sterile catgut it is, however, necessary to test both aerobically and anaerobically.

From the end of the last century when Lister, who first demonstrated the absorbability of catgut, sterilized his sutures by immersion in a strong phenol solution, until catgut offered for sale as sterile came within the purview of the Therapeutic Substances Act, many methods of ' sterilization ' used were as unreliable as they were numerous. They included the use of phenol, mercury compounds, essential oils, peroxide of hydrogen, iodine, silver salts, formaldehyde and heating in oil or alcohol (Holder, 1939).

The main faults included failure to kill spores (phenol, mercury compounds, essential oils) ; causticity (phenol) ; inhibition, giving an apparent but false sterility (mercury compounds); damage to the catgut (silver salts; iodine: acidity and water-logging; hot oil or alcohol: ' cooking ' of the gut); unintentional increase in resistance to absorption (iodine and formaldehyde).

Under the Therapeutic Substances Act, 1931, and subsequent regulations, manufacturers offering sterile surgical catgut for sale must be licensed by the Ministry of Health or by the Department of Health for Scotland. By the terms of the licence, the authorities must approve the premises in which sterilization is performed, the qualifications of the technical personnel and the processes used, whilst samples from every batch sterilized must be submitted to approved bacteriological test before the remainder may be sold.

A fundamental difficulty in sterilizing catgut is that the contaminating spores are not all on the surface of the strand. It will be remembered that in manufacturing raw catgut strings, ribbons of gut are twisted to form the strand. Spores present on the surface of the ribbons are thereby sealed into the interior of the string. The sterilizing agent, whether chemical or heat, must therefore reach and destroy the resistant spore envelopes without damaging the sensitive collagen of the catgut through which it must first pass.

Chemical sterilization is practicable under carefully controlled conditions, iodine sterilization having been employed for many years to give sterile catgut of excellent tensile strength and pliability. A serious objection to this method is that it is uneconomical, taking many weeks from start to finish and requiring much space and constant supervision to obtain optimum results. Another objection is that although no uncombined iodine need be left in the catgut, a change takes place in its chemical constitution which greatly prolongs the period required for absorption by the tissues (Holder, 1946). Although this was less serious than having the sutures absorbed too quickly, it was not uncommon to find fragments of catgut stitches expelled to the surface of a wound weeks after healing had taken place.

Heat sterilization has now largely replaced the chemical method. It has the great advantage of being a quick process which has little effect upon the absorption rate of the product and it has been improved to a stage which gives sterile catgut of excellent tensile strength and pliability.

Normally holding 15 to 20 per cent. of moisture, the catgut must be dried before a high temperature is applied otherwise the water present in it would cause ' cooking ' or partial hydrolysis with almost complete loss of tensile strength. The sterilizing temperature is critical, less than 150° C. being in-

sufficient for consistent sterility and more than 155° C. tending to cause brittleness. The heat must be applied evenly throughout the strand and for this reason hot air, which has a low heat conductivity factor, cannot be used for sterilizing.

The customary procedure is for the catgut to be coiled, placed in tubes open at one end, dried in ovens at a moderate temperature and then immersed for sterilization in a heated inert anhydrous fluid wherein the required temperature and time of exposure can be closely controlled.

The tubes of catgut are usually processed in suitable basket containers from which the oil can be drained after sterilization and, maintaining strictly aseptic conditions, a sterilized alcoholic reconditioning fluid, containing a predetermined proportion of water, is introduced and the open end of each tube is at once hermetically sealed.

Samples are taken from each batch of sealed tubes, some for bacteriological and some for physical tests, which must be passed before the remainder of the batch is released for sale.

' Multiple ' packings for sterile sutures, from which successive portions may be withdrawn for use on different occasions, are being discarded on safety grounds. With the sealed glass tube packing, any portion of the suture material not required on the occasion for which the tube was opened should be thrown away, not kept for use later with the consequent risk of contamination.

In order to clean the outsides of the sealed tubes before opening in the theatre, they may be washed in soapy water and stored in jars of antiseptic solution. Tubes which can be boiled or placed in in the sterilizer with the instruments before operation are obtainable, but most makers do not recommend this ' boilable ' pack. In order to avoid damage to the catgut during boiling or steam sterilizing the storage fluid in the tubes must be completely anhydrous ; catgut taken from such tubes is therefore brittle and wiry and its correct reconditioning in weak alcohol or physiological saline is a difficult procedure to control in the operating theatre.

Absorption

The rate of absorption of catgut in the body is usually determined in normal muscle such as the rectus abdominis.

Catgut which has not been specially treated to prolong its resistance to digestion lasts from 7 to 15 days in normal muscle; such catgut is known as ' plain.' In practice the, process of manufacture of raw catgut strings tends to harden them a little and most commercial ' plain ' catgut lasts from 14 to 21 days in normal muscle.

When used to suture the bowel, catgut usually lasts only one-third to one-quarter of its duration in muscle. Samples of hardened catgut, inserted through the gastric wall in rabbits and being in contact with the stomach contents, were absorbed in less than four days (Holder, 1946). Although wounds of the stomach wall heal with great rapidity, these experiments suggest that an absorbable suture may be contra-indicated where the stitches come into contact with the gastric juice.

It is customary for much of the catgut used in suturing to be hardened to prolong its absorption period. This is commonly achieved by the action of chrome salts, preferably in the ribbon stage of manufacture. Catgut containing the equivalent of approximately one-half per cent. Cr_2O_3 lasts for 20 to 30 days in normal muscle and for five to ten days in intestinal tissue. More resistant catgut may be obtained containing up to 1 per cent. Cr_2O_3.

Manufacturers usually control the absorption rate of their catgut by routine *in vitro* tests. These may take the form of hydrolysis time-checks in hot aqueous solutions or of enzyme digestion-periods of catgut strands under tension, using pepsin or better an alkaline-acting enzyme such as papain or trypsin. The ideal control is the implanting of catgut into living animal tissue (Holder, 1946). This may be performed by closing an incision in the dorso-lumbar muscle of rabbits with interrupted stitches and observing, at re-operation at a later date, the breaking strain of the stitches with the aid of an accurate spring balance.

The loss of strength of catgut stitches by digestion, when plotted against time, gives a straight-line graph so that the date after which effective holding power (which may be regarded as 450 gm. or 1 lb.) would be lost can be calculated. Generally speaking, it is safer to have catgut resist absorption for too long rather than for too short a time.

It is often recommended that only plain catgut should be used in subcutaneous or fatty tissue. This, however, leads to another interesting point, namely the reaction of the tissues to the introduction of catgut stitches. The significant factors are :—the more truly ' plain ' the catgut and the thicker the strand, the greater is the local reaction (Jenkins, 1942).

The first reaction in the tissues after implanting catgut is a concentration of polymorphonuclear leucocytes. If the catgut is quite unhardened, digestion proceeds at such a pace that there is soon a marked collection of detritus, formed largely of disintegrated leucocytes. If the catgut is more resistant than the plain variety, little or no detritus is observable and digestion proceeds mainly by the ingrowth of giant-cells. Such reaction as takes place is greater with a thick suture than with a fine one, particularly with plain catgut.

A tendency to use thick catgut at operation is due to an unfounded fear that fine stitches may be insufficiently strong to hold the wound edges in apposition. Great force is not normally necessary to keep a wound closed and even if considerable strain is expected, as in retching or coughing after laparotomy, it is more likely that the sutures would cut out of the tissues than that the stitches themselves would break.

The shearing strain of tissues, which is analogous to their resistance to the cutting out of stitches, is not so high as appears to be generally believed, varying from less than 1 lb. in soft tissue, as for instance bowel, to no more than $2\frac{1}{4}$ lb. in rectus muscle sheath. The minimum standard breaking strain for No. 2/0 catgut, even when knotted, is 3 lb. This bears out the experiments of various workers who advocate the use of finer catgut sutures than those commonly used, with No. 0 for fascia as the thickest recommended, down to No. 3/0 or No. 4/0 for muscle, peritoneum and subcutaneous tissue (Howes, 1929, 1941).

Suspected infection in a wound need not be a reason for using thick catgut ; besides the addition of ' thick catgut reaction ' to the bacterial disturbance, it is by no means certain that a moderate infection speeds up the absorption of catgut excessively. In a summary of a large number of abdominal wound disruptions, it was found that the cases in which infection was present disrupted considerably *later* than the clean cases.

Furthermore, with the considerable improvements in the manufacture of surgical catgut over recent years resulting in greater tensile strength, there is no justification on this score for using the thicker sizes.

Conclusion

To summarize the points covered in this general survey of catgut as a suture material :—

1. The fundamental advantage of catgut is its absorbability.

2. It has excellent tensile strength.

3. Sterility, as taken from the sealed tubes, is assured.

4. A hardened or ' chromed,' catgut is preferable to the ' plain ' variety.

5. The finest possible sizes should be used in preference to thicker sizes.

In conclusion, the following quotation from Mikulicz is offered with respect and sincerity:—

' *Je reconnais le bon chirurgien, non pas à la façon dont il coupe, mais à la façon dont il sait recoudre.*'

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HIND-QUARTER AMPUTATION

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Hind-quarter amputation was first performed in 1891 by Billroth (1902), but it was not until 1895 that a successful result was obtained by Girard (1895). Since that time the operation has been performed by many surgeons with increasing success. Pack and Ehrlich (1946) report that 132 cases are recorded in surgical literature over the last 50 years. Sir Gordon Gordon-Taylor, in 1946, reported a personal series of 21 cases, and since that time has performed a further 11 such operations ; it is largely as a result of his work that this formidable ablation has been established in this country as a standard procedure in the surgical management of malignant disease.

In most cases the operation is performed for primary malignant tumours of the bones or connective tissues of the pelvis, or for similar tumours in the upper third of the thigh which have extended too far proximally to allow of disarticulation through the hip-joint ; typical of the tumours necessitating this procedure are those illustrated in Figs. 1 and 2. On occasion the operation has been performed for extensive tuberculous or chronic inflammatory disease of the hip and pelvic bones. By virtue of their less sinister pathological potentialities, the best results are obtained in cases where the tumour is essentially only of local malignancy, such as infiltrating chondromas of the